General Physics I Lab (PHYS-2011)

Experiment MEAS-1:

MEASUREMENT

Objective:

This laboratory exercise will be performed over two consecutive weeks. During the first week, students will learn about the techniques used in making measurements in length and mass. During the second week, students will be involved in making measurements in time. There will be only one lab report (worth 20 points) required for this two week lab. This lab report is to be turned in at the beginning of the fourth week's laboratory class.

Introduction:

Every tool or instrument used in making measurements is limited in precision. This limit is typically described in terms of the least count of the instrument. This is the size of the smallest division on a scale. The meter stick and ruler have a least count of 0.1 cm (or 1 mm). Each measurements in your table must be accompanied by the least count of the instrument used to make the measurement. All measurements should be reported to **at least** the precision of the least count.

NOTE: Each student in a given group is to make at least one measurement for each dimension for each experiment.

Measurement Instruments:

Today you will gain experience in making measurements in length and mass, properly reporting these measurements, and techniques used in analyzing these data. You will use a meter stick, vernier caliper, and micrometer caliper to measure lengths with increasing precision. A laboratory balance will be used to measure mass.

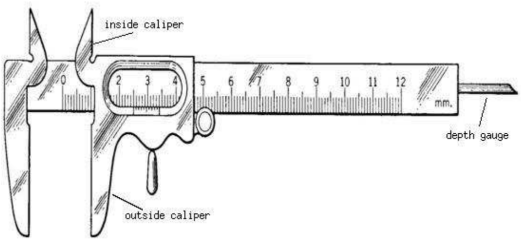
Measurements with a Meter Stick

Every tool or instrument used in making measurements is limited in precision. This limit is typically described in terms of the least count of the instrument. This is the size of the smallest division on a scale. The meter stick that will be used today has a least count of 0.1 cm (= 1 mm). Each table of measurements in your lab report must be accompanied by the least count of the instrument used to make the measurement. This provides at least a first estimate of the precision of the measurement. All measurements should be reported to at least the precision of the least count.

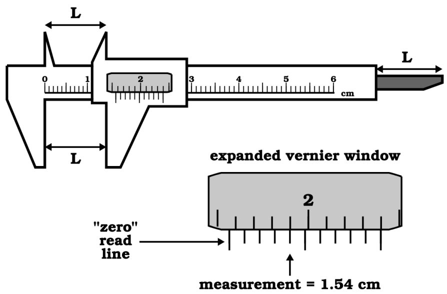
You should also look carefully at the reading of the measurement instrument when the measurement should read zero. If the instrument does not "read zero," this may be a source of zero error, which may systematically bias your results. Most of our instruments should have a zero error less than the least count. If this is not true, one needs to properly account for the zero error in recording the results of a measurement.

Measurements with a Vernier Caliper

The vernier caliper is used to measure length and provides a high precision length measurement using its inside caliper, outside caliper, or depth gauge. It indicates length on a fixed graduated scale (we will use the "centimeter", not the "inch" scale) which is augmented by the movable vernier scale. In the example figure below, we note that the "zero read line" on the movable component of the caliper is located just past the 1.5 cm marker and just before the 1.6 cm marker on the fixed scale. From this, we know that the length measurement will be somewhere between 1.5 cm and 1.6 cm. Next we examine the fixed scale (upper scale in the "expanded vernier window") and look for where the marker on this fixed scale lines up with the line on the movable component of the of the caliper (the lower scale in the "expanded vernier window"). We see that the alignment takes place with the 4th marker past the zero read line on the movable scale. This means that the length we have measured corresponds to 1.54 cm. From this measurement, we see that a vernier caliper has a precision of 0.01 cm or 0.1 mm.



(a) The Vernier Caliper.



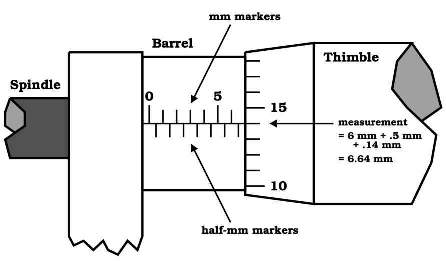
(b) Example on how to read a Vernier Caliper.

Figure 1: Vernier Caliper

Measurements with a Micrometer Caliper

The vernier caliper has a factor of 10 increase in precision compared to the meter stick while the micrometer caliper extends the precision of length measurement by another factor of 10 by using a finely pitched screw and a circular (rotating) scale. There are two different versions of the micrometer caliper used in this course, one with the rotating circular scale in half-millimeter increments, and the other in full-millimeter increments. Figure 2.a shows the half-millimeter version and the diagram in 2.b displays how to read this type of caliper. The location of the circular scale along the scale of the barrel marks the length nearest half-millimeter or millimeter. The reading on the circular scale that intersects the line of the barrel's scale gives the additional length in hundredths of a mm.

(a) The Micrometer Caliper.



(b) Example of how to read a Micrometer Caliper.

Figure 2: Micrometer Caliper

Mass Measurements with a Beam Balance

The precision beam balance (shown below in an image from PASCO Scientific Instruments) will be used to measure mass. The Ohaus triple-beam mechanical balance (shown in Figure 3) has been a standard weighing instrument in undergraduate physics laboratories for decades. It's accurate, easy to use, and durable. One places the object on the balance pan, then move the balancing mass(es) on the horizontal tracks until the indicator on the right side points to the '0' (zero) mark. Then one takes the sum of the readings on each of the scales to determine the measured mass of the object. Determine the least count and zero error of the balance and record this data.

Figure 3: Ohaus Triple-Beam Balance

Table 1: Mass Densities of Various Materials

Material	**Density (gm/cm^3)**	**Density (kg/m^3)**
Aluminum	2.73	2730
Steel	7.80	7800
Brass	8.74	8740
Walnut	0.67	670
Basswood	0.50	500

Week 1 - Procedure:

Measurement Procedure

Part A-1: Rectangular Block

1. Using a meter stick, measure the dimensions of the rectangular block at your work station and record your data in Table 1 in units of (mm), (cm) and (m). Record the zero offset of your measurement on your data sheet. The precision of a meter stick is 1.0 (mm) or 0.01 (cm).
2. Calculate the radius, surface area ($A = 2LW + 2LH + 2WH$) and the volume ($V = LWH$) of the block. Record your data in Table 3.
3. Using a beam balance, measure the mass of the rectangular block and record your measurement in the table in (kg) and (g). 1g = 0.001 kg.
4. Calculate the density of the rectangular block $\rho = M/V$. Record in (kg/m^3) in column 2 and g/cm^3 in column 3.

Part A-2: Cylindrical Objects

1. Using a Vernier Caliper, measure the dimensions of the cylindrical object at your work station and record your data in Table 2 in units of (mm), (cm) and (m). Record the zero offset of your measurement on your data sheet. The precision of the caliper is 0.005 (mm).
2. Calculate the surface area (A) $= 2\pi r_{avg}H + 2\pi r_{avg}^2$. Record your data results in (m^2, cm^2, mm^2) in Table 3.
3. Calculate the cylindrical volume (V) $= \pi r_{avg}^2$H. Record your data results in (m^3, cm^3, mm^3) in Table 3.
4. Using a beam balance, measure the mass of the cylindrical object and record your measurement in the table in (kg) and (g). 1g = 0.001 kg.
5. Calculate the density of the cylindrical object $\rho = M/V$. Record in (kg/m^3) in column 2 and g/cm^3 in column 3.
6. The cylindrical object is composed of Basswood. Record the composition on your data sheet.

Part A-3: Steel Ball

1. Using a Vernier Caliper or a Micrometer, measure the diameter of the steel ball bearing and record your data in Table 3 in units of (mm), (cm) and (m). Record the micrometer zero offset on your data sheet.
2. Calculate the radius, surface area ($A = 4\pi r^2$) and the volume ($V = \frac{4}{3}\pi r^3$) of the sphere. Record your data in Table 3.
3. Using a beam balance, measure the mass of the steel ball and record your measurement in the table in (kg) and (g). 1g = 0.001 kg.
4. Calculate the density of the steel ball $\rho = M/V$. Record in (kg/m^3) in column 2 and g/cm^3 in column 3.

Week 2 - Measurement With a Pendulum:

Consider a pendulum bob of mass m hanging from a support rod at a distance L from the pivot point. If the pendulum bob is moved θ degrees from the equilibrium position (defined by a vertical line pointing towards the ground) and released, the bob will oscillate back and forth about the equilibrium position (see Figure 4a below). Assuming there is no friction between the support rod and the axis on which the rod is connected, this oscillation will continue as a result of the forces acting on the pendulum bob: the tension acting along the support rod and the weight of bob, w=mg. These forces add to produce a resulting force that is tangential to the curved "dashed" path in Figure 4a. This tangential force acts to restore the pendulum to its equilibrium position.

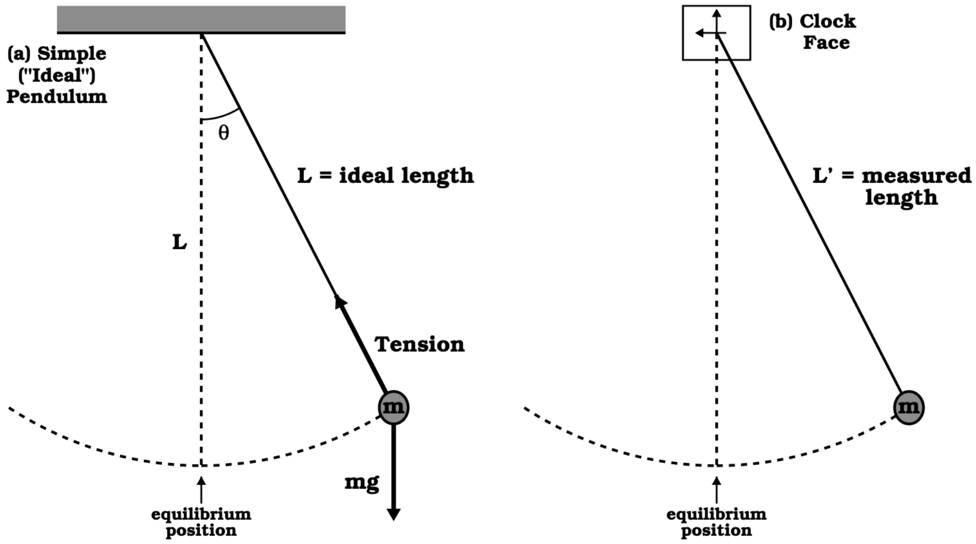


Figure 4: The ideal pendulum and the clock pendulum.

The period T of a simple, or ideal, pendulum is defined as the time required to complete one cycle of the pendulum. A "complete cycle" is defined by the pendulum bob returning to its starting position. To demonstrate this, consider Figure 4a. The pendulum bob is drawn as a filled-in circle connected to the support rod (i.e., the solid line) at an angle θ from the vertical equilibrium position. If the pendulum bob starts from the extreme right side of the oscillation (i.e., the right end of the dashed curved line), half a cycle occurs when the pendulum moves through the equilibrium position and continues to the extreme left side of the oscillation (i.e., the left end of the dashed curved line). The "full" cycle is complete when the pendulum moves in the opposite direction through the equilibrium position and ends up back to where it started. If the pendulum oscillates at small angles ($\theta < 30°$), then the period of oscillation depends only on the length of the support rod and the gravitational acceleration g.

For this experiment, we will be using a **clock pendulum**, whose motion we approximate as being that of a simple pendulum, located on the front wall in the room as drawn in Figure 4b. Where as we have a support rod length of L in our ideal pendulum, we will represent the length of our clock pendulum as L'. **The length of the clock pendulum support rod has already been measured by the staff of the Physics and Astronomy Department, and its length is $L' = 82.1$ cm**. Note that this length has 3 significant digits.